

APPENDIX G. ALARA PRINCIPLE

G.1 REGULATORY GUIDANCE ON ALARA

The U.S. Department of Energy (DOE), Nuclear Regulatory Commission (NRC), and California Department of Health Services (DHS) regulations and guidance require the implementation of the “as low as reasonable achievable” (ALARA) process. ALARA is defined as:

“[T]he approach to radiation protection to manage and control exposures (both individual and collective) to the work force and to the general public to as low as is reasonable, taking into account social, technical, economic, practical and public policy considerations.” (10 CFR 835.2(a) and 10 CFR 834.2(a))

“ ‘[R]easonably achievable’ is judged by considering the state of technology and the economics of improvements in relationship to all the benefits from these improvement. However a comprehensive consideration of risks and benefits will include risks from non-radiological hazards. An action taken to reduce radiation risks should not result in a significantly larger risk from other hazards.” (NUREG 1727 [NRC 2000] and NRC Regulatory Guide 8.8 [NRC 1978])

“Determination of the levels which are ALARA must take into account consideration of any detriments, such as traffic accidents, expected to potentially result from decontamination and waste disposal.” (10 CFR 20.1403(a))

The ALARA process is defined as:

“[A] logical procedure for evaluating alternative operations. Processes, and other measures, taking into account factors that relate to societal, technological, economic, practical, and public policy considerations in order to make a judgment with respect to what constitutes ALARA.” (10 CFR 834.2(a))

The Nuclear Regulatory Commission has made certain statements related to cleanup levels that are already deemed ALARA:

“In light of the conservatism in the building surface and surface soil generic screening levels developed by the NRC staff, the staff presumes, absent information to the contrary, that licensees or responsible parties that remediate building surfaces or soil to the generic screening levels do not need to demonstrate that these levels are ALARA.” (NRC 2000, Appendix D, “ALARA Analysis,” page D1)

“For residual radioactivity in soil at sites that will have unrestricted release [*i.e.*, meet 25 millirem per year], generic analyses show that shipping [additional] soil to a low-level waste disposal facility [to achieve goals less than 25 millirem per year] is unlikely to be cost effective, largely because of the high costs of waste disposal.” (NRC 2000, Appendix D, “ALARA Analysis,” page D12)

Thus, the ALARA process is an “impact analysis” of the detriments and benefits of different cleanup levels. Rocketdyne utilized the modeling and data recommended in NUREG 1727, Appendix D, “ALARA Analysis” (NRC 2000), to assess the impact of various cleanup levels in the range of 0 to 15 millirem per year. Various impacts of Alternatives 1 and 2 were calculated, including person-rem

averted (and associated lives saved), fatalities from worker accidents, truck accidents, and soil volumes excavated.

G.2 EXISTING CLEANUP STANDARDS ARE ALARA

The two principal cleanup goals are related to building facility surface contamination and soil volumetric contamination.

Building Surface Contamination. The recent *Surface and Volume Radioactivity Standards for Clearance* (ANSI/HPS 1999) has proposed new isotope specific standards for surface and volumetric contamination based on a 1-millirem-per-year standard. A comparison of the Regulatory Guide 1.86 limits (NRC 1974) (those currently utilized by NRC, DOE, DHS, and Rocketdyne) with these new proposed limits shows that Regulatory Guide 1.86 limits are equal or less than 1 millirem per year, thus demonstrating that cleanup standards for building surfaces are much less than a 15 millirem per year goal (Boeing 2001). Table G-1 illustrates this comparison.

Table G-1. Dose Equivalent to Regulatory Guide 1.86 Surface Contamination Limits

	Regulatory Guide 1.86		Recommended screening limits based on 1 mrem/y in ANSI/HPS 13.12-1999		First year dose equivalent to Reg. Guide 1.86 limits	First year risk equivalent to Reg. Guide 1.86 limits ^a
	dpm/100cm ²	Bq/cm ²	dpm/100cm ²	Bq/cm ²	mrem/year	
Transuranics (Pu-239, Pu-240, Pu-241, Am-241, etc.)	100	0.0166	600	0.1	0.166	8.3E-08
Ra-226, Ra-228	100	0.0166	600	0.1	0.166	8.3E-08
Th-228, Th-230	100	0.0166	600	0.1	0.166	8.3E-08
Thorium -nat, Th-232	1,000	0.166	600	0.1	1.66	8.3E-07
Strontium -90 (isolated)	1,000	0.166	6,000	1	0.166	8.3E-08
Uranium -nat, U-234, U-235, U-238	5,000	0.833	6,000	1	0.833	4.2E-07
Beta-gamma emitters (e.g., Cs-137, Co-60)	5,000	0.833	6,000	1	0.833	4.2E-07
Beta-gamma emitters (e.g., I-131)	1,000	0.166	60,000	10	0.0166	8.3E-09
Beta-gamma emitters (e.g., Fe-59)	5,000	0.833	60,000	10	0.0833	4.2E-08
Beta-gamma emitters (e.g., H-3, Fe-55, Ni-63)	5,000	0.833	600,000	100	0.00833	4.2E-09

a. Based on a lifetime cancer risk of 5×10^{-7} per millirem
Source: Boeing 2001.

Soil Volumetric Contamination. Table G-2 uses the RESRAD software to calculate isotope-specific dose risk correlations. Columns 5 and 7 show the soil concentration equivalent to a 15-millirem per year dose limit using the 2001 version of RESRAD (version 6.1) (ANL 2001). These are very similar to the data in Column 2 from *Approved Sitewide Release Criteria for Remediation of Radiological Facilities at*

Table G-2. Soil Cleanup Goals

Isotope	RESRAD (1996)			RESRAD Version 6.1			Derived Risk Standards based on RESRAD 6.1					
	N001SRR140131 15 mrem/y dose based standard			15 mrem/y dose based standard			3 x 10 ⁻⁴ risk based standard			1 x 10 ⁻⁶ risk based standard		
	Soil	Soil ^a	Risk ^b	Dose	Risk	Soil	Risk	Dose	Soil	Risk	Dose	Soil
	pCi/g	pCi/g		mrem/y		pCi/g		mrem/y	pCi/g		mrem/y	pCi/g
Am-241	5.44	5.44	1.1E-05	15	1.1E-05	5.53	3.0E-04	405	149	1.0E-06	1.35	0.50
Co-60	1.94	1.94	8.5E-05	15	9.1E-05	2.07	3.0E-04	49	6.8	1.0E-06	0.16	0.02
Cs-134	3.33	3.33	3.3E-05	15	3.9E-05	3.92	3.0E-04	114	29.9	1.0E-06	0.38	0.10
Cs-137	9.20	9.20	2.4E-04	15	2.5E-04	9.31	3.0E-04	18	11.4	1.0E-06	0.06	0.04
Eu-152	4.51	4.51	1.7E-04	15	1.8E-04	4.63	3.0E-04	26	7.9	1.0E-06	0.09	0.03
Eu-154	4.11	4.11	1.3E-04	15	1.4E-04	4.27	3.0E-04	33	9.4	1.0E-06	0.11	0.03
Fe-55	629,000	629,000	1.6E-04	15	2.0E-04	764,500	3.0E-04	22	1,143,890	1.0E-06	0.07	3813
H-3	31,900	31,900	2.1E-04	15	2.9E-05	4,511	3.0E-04	154	46,457	1.0E-06	0.51	155
K-40	27.6	27.6	2.4E-04	15	2.5E-04	28.1	3.0E-04	18	33.9	1.0E-06	0.06	0.11
Mn-54	6.11	6.11	1.4E-05	15	2.0E-05	8.92	3.0E-04	221	131	1.0E-06	0.74	0.44
Na-22	2.31	2.31	3.9E-05	15	4.5E-05	2.66	3.0E-04	99	17.6	1.0E-06	0.33	0.06
Ni-59	151,000	151,000	8.6E-04	15	8.7E-04	153,900	3.0E-04	5	52,905	1.0E-06	0.02	176
Ni-63	55,300	55,300	6.9E-04	15	7.0E-04	56,260	3.0E-04	6	24,067	1.0E-06	0.02	80.2
Pu-238	37.2	37.2	1.3E-05	15	3.2E-05	90.9	3.0E-04	140	849	1.0E-06	0.47	2.83
Pu-239	33.9	33.9	1.4E-05	15	3.3E-05	82.1	3.0E-04	136	746	1.0E-06	0.45	2.49
Pu-240	33.9	33.9	1.4E-05	15	3.3E-05	82.1	3.0E-04	137	749	1.0E-06	0.46	2.50
Pu-241	230	230	1.2E-05	15	1.2E-05	234	3.0E-04	361	5,643	1.0E-06	1.20	18.8
Pu-242	35.5	35.5	1.3E-05	15	3.3E-05	86.3	3.0E-04	137	790	1.0E-06	0.46	2.63
Ra-226	0.20	5 and 15	5.0E-03	15	2.6E-04	0.26	3.0E-04	17	0.3	1.0E-06	0.06	0.0010
Sr-90	36	36	1.9E-04	15	1.9E-04	36.6	3.0E-04	24	57.9	1.0E-06	0.08	0.19
Th-228	2.81	5 and 15	5.2E-05	15	3.7E-05	3.61	3.0E-04	120	28.9	1.0E-06	0.40	0.10
Th-232	1.53	5 and 15	9.5E-04	15	3.4E-04	1.77	3.0E-04	13	2	1.0E-06	0.04	0.0053
U-234	106	30	3.1E-05	15	1.2E-04	114	3.0E-04	39	294	1.0E-06	0.13	0.98
U-235	32.1	30	2.3E-04	15	2.9E-04	38.3	3.0E-04	15	39.4	1.0E-06	0.05	0.13
U-238	90.9	35	6.3E-05	15	2.2E-04	122	3.0E-04	20	166	1.0E-06	0.07	0.55
Average				15	1.8E-04							

a. Includes non-RESRAD ARAR soil standards for Ra-226, Th-238, Th-232, U-234, U-235, and U-238.

b. Equivalent risk of approved cleanup standards based on the U.S. Environmental Protection Agency's (EPA) Health Effects Assessment Summary Tables (HEAST) (EPA 2001) morbidity dose/risk factors in RESRAD 6.1 (ANL 2001) and 30 year exposure period.

the SSFL (Boeing 1999) using the 1996 version of RESRAD. Column 6 shows the equivalent morbidity risk calculated by RESRAD based on the U.S. Environmental Protection Agency's Health Effects Assessment Summary Tables (HEAST) (EPA 2001) morbidity dose/risk factors and a 30-year exposure period. The risks for 15 millirem per year range from a high of 8.7×10^{-4} for nickel-59 to a low of 1.1×10^{-5} for americium-241. Thus, the range of risk factors are from 3x to 1/30x, the rule of thumb of 3×10^{-4} . The risk factor for cesium-137 is 2.5×10^{-4} , and the average risk for all radionuclides is 1.8×10^{-4} . Therefore, implementing a 15-millirem-per-year dose goal actually achieves many isotope-specific theoretical risks within the 10^{-6} to 10^{-4} risk range.

G.3 DEMONSTRATION OF ALARA EFFECTIVENESS WITH POST-REMEDIATION SAMPLING

The cleanup process, whether for building surfaces or soil, typically achieves much lower post-remediation levels than regulatory cleanup goals.

Building Surface Contamination. As an example, Table G-3 shows surface contamination measurements for total and removable beta contamination for survey unit 9, the vacuum equipment room within the Building 4059 basement. This facility was remediated and surveyed in 1999. This area had the highest removable contamination measurement and one of the highest total contamination measurements. All total measurements were below not only the cleanup standard of 5,000 disintegrations per minute per 100 square centimeters but also below the minimum detectable activity of 2,217 disintegrations per minute per 100 square centimeters. Forty percent of the removable measurements were less than the removable minimum detectable activity of 14 disintegrations per minute per 100 square centimeters. All removable measurements were less than 5 percent of the cleanup standard of 1,000 disintegrations per minute per 100 square centimeters.

Table G-3. Contamination Measurements for Vacuum Equipment Room of Building 4059^a

	Maximum Beta (dpm/100 cm ²)	Minimum Beta (dpm/100 cm ²)	Average Beta (dpm/100 cm ²)	Minimum detectable activity (MDA) (dpm/100 cm ²)	Cleanup Standard (Reg. Guide 1.86) (dpm/100 cm ²)
Total	652	-78	107	2,217	5,000
Removable	54	2	18	14	1,000

a. Rocketdyne 1999.

Soil Volumetric Contamination. As an example of the ALARA process for cleanup of soil volumetric contamination, cesium-137 data for the land where the Hot Lab stood can be examined (*see* Table G-4). The majority of samples (83 percent or 70 of 84) were within the 95 percent confidence limit of 0.21 picocurie per gram for local background. Seventeen percent of samples exceeded this 0.21 picocurie per gram local background level, indicating potential man-made contamination. Only four samples (5 percent) exceeded 1.0 picocurie per gram. The maximum sample was 4.6 picocuries per gram net, or half the cleanup standard. No samples exceeded the cleanup standard of 9.2 picocuries per gram. This illustrates the ability of backhoe excavation operations and instrument screening techniques to achieve cleanup of soil significantly below approved cleanup standards.

Table G-4. Hot Lab Cesium-137 Soil Data^a

Item	Data
No. of Samples	84
Maximum measured Cs -137 pCi/g (gross)	4.83
Minimum measured Cs -137 pCi/g (gross)	0.012
Mean measured Cs -137 pCi/g (gross)	0.26
Number of non-detects < ~ 0.01 pCi/g	12
Number less than bkgd of 0.21 pCi/g	70
Percent less than bkgd of 0.21 pCi/g	83%
Number greater than standard of 9.2 pCi/g (net)	Zero

a. Rocketdyne 2000.

Using the distribution of soil data for cesium-137 at the Hot Lab, a theoretical average risk for the 0.02-square-kilometer (5-acre) Hot Lab site can be calculated to be 5×10^{-6} , assuming the linear-no-threshold model is valid at the site average dose of 0.24 millirem per year.

Averaging Soil Data in Risk Analysis. Comments have been made questioning the use of averaging site risk. Some would say that in the case study above, the dose and risk should be calculated based on the maximum soil sample data, namely 4.6 picocuries per gram, giving 7.5 millirem per year or a theoretical risk of 1.5×10^{-4} . However, averaging is a valid and defensible technique and supported by regulation. Indeed, the computer model that is used to calculate soil concentration cleanup standards based on 15 millirem per year assumes uniform soil contamination for a 10,000-square-meter (108,000-square-foot) area and to a depth of 1 meter (3 feet). This is equivalent to 10,000 cubic meters (353,000 cubic feet) or 14,000 metric tons (15,000 tons) of contaminated soil. An area 10,000 square meters is approximately 2 acres and is similar to the assumed lot size of potential post-release development in Area IV. An individual is not expected to sit immobile over the maximally contaminated location for a 40-year exposure period. If smaller and smaller areas (and volumes) of contaminated soil are assumed in the computer models, higher values are obtained for soil concentration cleanup standards. Looking at it from another perspective, a 0.5-kilogram (1-pound) soil sample would not be expected to (and indeed does not) give the same dose as similarly contaminated 14,000 metric tons.

Current Onsite Radiation Risks of SSFL Soil. Based on the post-remedial soil sampling and assuming that the linear-no-threshold model is valid at low doses, the theoretical risk from soil at Area IV and at various major facilities can be calculated (*see* Table G-5).

Table G-5. Theoretical Existing Risk Levels of Contaminated Soil in Area IV and Major Facilities^a

Facility/Area	Area (acres)	No. soil samples	Cs-137 Range (pCi/g net)	Average Risk ^b	Max. Risk ^c	Comments
Area IV	290	149	ND - 2.2	1.8×10^{-6}	7.2×10^{-5}	
Hot Lab	5	84	ND - 4.6	4.8×10^{-6}	1.5×10^{-4}	Remediated
FSDF	3	78	ND - 0.57	2.7×10^{-7}	1.2×10^{-5}	Remediated and released for unrestricted use
RMHF	3	29	ND - 52	1.5×10^{-4}	1.7×10^{-3}	Remediation planned

FSDF = Former Sodium Disposal Facility

RMHF = Radioactive Materials Handling Facility

a. Risk values calculated using the linear-no-threshold model, assuming it is valid at these low dose levels (*see* Appendix C).

b. Based on full range of cesium -137 sample data for that facility.

c. Conservatively assuming that all of the facility is contaminated at the maximum cesium -137 level for that facility.

From Table G-5, it can be seen that the facility average risk for Area IV as a whole and the Hot Lab fall in the lower end of the risk range of 10^{-6} to 10^{-4} . The Former Sodium Disposal Facility falls below 10^{-6} . Even using the maximum measured cesium-137 value, both Area IV and the Former Sodium Disposal Facility meet the 10^{-6} to 10^{-4} risk range. Using the maximum cesium level for the Hot Lab, it meets the 3×10^{-4} cleanup standard of Alternative 1. Even the Radioactive Materials Handling Facility soil (which has not yet been remediated) meets the 3×10^{-4} cleanup standard of Alternative 1 if averaging is used. However, in compliance with DOE's ALARA policy, this soil will be remediated to well below approved cleanup standards.

These numbers are calculated using the linear-no-threshold model, assuming it is valid at these low dose levels. Using the same model, the inherent risk level of clean, uncontaminated soil, as a result of naturally occurring radionuclides, is approximately 10^{-3} or 1-in-1,000, due to a dose rate of 30 to 50 millirem per year.

G.4 REFERENCES

- ANL (Argonne National Laboratory), 2001. RESRAD, Version 6.1, computer codes developed by the Environmental Assessment Division of Argonne National Laboratory, July 27, 2001.
- ANSI/HPS (American National Standards Institute/Health Physics Institute), 1999. *Surface and Volume Radioactivity Standards for Clearance*, ANSI/HPS N13.12-1999, McLean, Virginia, August 31, 1999.
- Boeing, 2001. *Dose Equivalent to Regulatory Guide 1.86 Surface Contamination Limits*, prepared by P. Rutherford (spreadsheet/electronic file), January 11, 2001.
- Boeing, 1999. *Approved Sitewide Release Criteria for Remediation of Radiological Facilities at the SSFL*, N001SRR140131, prepared by Rocketdyne for the U.S. Department of Energy, February 18, 1999.
- EPA (U.S. Environmental Protection Agency), 2001. Health Effects Assessment Summary Tables (HEAST), April 16, 2001.
- NRC (U.S. Nuclear Regulatory Commission), 2000. *NMSS Decommissioning Standard Review Plan*, NUREG 1727, Section 7 and Appendix D, "ALARA Analysis," Division of Waste Management, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C., September 2000.
- NRC (U.S. Nuclear Regulatory Commission), 1978. *Information Relevant To Ensuring That Occupational Radiation Exposures At Nuclear Power Stations Will Be As Low As Is Reasonably Achievable*, Regulatory Guide 8.8, June 1978.
- NRC (U.S. Nuclear Regulatory Commission), 1974. *Termination of Operating Licenses for Nuclear Reactors*, Regulatory Guide 1.86, June 1974.
- Rocketdyne, 2000. *Area 4020, MARSSIM Final Status Survey*, Rocketdyne Report No. RS-00010, October 31, 2000.
- Rocketdyne, 1999. *Building 4059, Final Status Report (Phase I)*, Rocketdyne Report No. RS-00008, September 11, 1999.